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CONCURRENT PERFORMANCES: EFFECT OF PUNISHMENT CONTINGENT ON THE SWITCHING RESPONSE[1]

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Pigeons' key-pecking responses were maintained under concurrently available variable-interval schedules of reinforcement. Responses in the presence of two different key-colors were reinforced on two independent and concurrent variable-interval schedules of food reinforcement, each associated with one of the key colors (red or green). Pecks at a second key (changeover key), always white, would alternate the colors on the main key. In Exp. 1 and 2, electric shock of 50 msec duration followed immediately after changeovers. The proportion of responses in the presence of the color associated with the higher frequency of reinforcements per hour was a direct function of shock intensity contingent on changeovers. When both schedules provided equal number of reinforcements per hour, there was no systematic effect of shock intensity on response distribution. In Exp. 3, a timeout period was contingent on changeovers, and response distribution was a function of timeout length.

CONTENTS

When pigeons and rats are free to emit two incompatible responses, each reinforced under an independently arranged variable-interval (VI) schedule, responses tend to be distributed proportionally to the relative frequency of reinforcements provided by each schedule (Herrnstein, 1961; Catania, 1963). A high frequency of alternation between the incompatible responses has been observed in such situations (Skinner, 1950; Findley, 1958).

The shifting of responding from one schedule to another is called a changeover (CO). The response of changing over from one schedule to another can be made explicit by requiring that a third response be emitted between responses associated with the concurrent VI schedules (Findley, 1958). When the frequency of changeovers is decreased by a changeover delay (COD), the proportion of the total number of responses associated with a given schedule approximates the proportion of obtained reinforcements associated with that schedule (Herrnstein, 1961; Catania, 1963). The COD specifies a minimum time after a changeover during which a response cannot be reinforced (Herrnstein, 1961). If a reinforcement for response A was scheduled while the subject was emitting response B, response A will be reinforced only after the COD duration has been terminated.

Pliskoff (1966) and Shull and Pliskoff (1967) showed that manipulations in COD duration could affect the proportion of responding controlled by each VI schedule. However, the use of a COD to decrease changeover rates has at least one disadvantage. Extreme values of COD might interfere with the schedule of VI reinforcement, should some of the intervals be smaller than the COD duration. The present investigation sought to explore the effects of two other kinds of variables, electric shock and timeout, from the experimental situation on concurrent performances of pigeons. Reduc-

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tions in changeover rates might be obtained with manipulations in shock intensity or in timeout duration without interfering with the schedule of positive reinforcement. Through manipulations of the intensity of brief electric shocks and of the duration of periods of timeout contingent on the switching response, the rate of changeovers was altered. The effects of such manipulations on the distribution of responses and time spent on the presence of each schedule were observed.

EXPERIMENT 1: ELECTRIC SHOCKS CONTINGENT ON CHANGEOVERS

It has been shown that moderate to severe shock intensities will decrease the rate of an operant when shock is delivered contingent upon emission of that operant (Azrin, 1960; Appel, 1963). In Exp. 1, it was assumed that if changeovers are operants, their rates might be depressed by punishment also. The use of brief electric shocks to reduce changeover rates should make it possible to obtain drastic reductions in alternations without necessarily interfering with reinforcement intervals. Thus, it should be possible to observe changes in response and time distribution correlated with changes in the rate of changeovers without alterations in reinforcement distribution.

METHOD

Subjects

Four adult male, experimentally naive Silver King pigeons were maintained at about 80% of their body weight, determined during a period of free access to food.

Apparatus

A standard experimental chamber for operant conditioning studies with pigeons (Ferster and Skinner, 1957) was used. Two response keys, made of white plastic, were located on one wall. The right response key could be transilluminated by a green or a red light; the left key was always transilluminated by white light. An opening for the presentation of food (grain) was located below the two response keys, centered on the wall. The chamber was illuminated from the beginning to the end of the experimental session by two houselights, located on the upper corners of the wall. During reinforcements (presentation of grain), the houselights and response key lights went off, and the feeder opening illuminated.

Procedure

The changeover (CO) key procedure of concurrent scheduling described by Findley (1958) and modified by Shull and Pliskoff (1967) was used. In this procedure, both VI schedules are arranged on the same key (main key), each associated with a different exteroceptive stimulus. Pecks on a second key (CO key) would change the color of the main key and the VI schedule associated with that color. The schedules were VI 1-min, VI 3-min for two subjects, and VI 1.5-min, VI 1.5-min for the other two birds. In the present experiment, as in Shull and Pliskoff (1967), the changeover operandum would become inoperative after each switching response until at least one response was made on the main key. No changeover delay was in force after a response on the changeover key, nor after main key responses.

The intensity of electric shock, delivered after every peck on the CO key, was manipulated (at no time were responses on the main key followed immediately by shock). The resulting changes in the following variables were investigated:

(a) rates of changovers (changeovers per minute);

(b) proportion of responses in the presence of the red key color, *i.e.*,

$$\frac{R_R}{R_R + R_G} \text{ (Rel Resp);}$$

(c) proportion of time spent in the presence of the red key color, *i.e.*,

$$\frac{T_R}{T_R + T_G} \text{ (Rel Time);}$$

(d) proportion of reinforcers obtained in the presence of the red key color, *i.e.*,

$$\frac{r_R}{r_R + r_G} \text{ (Rel Reinf);}$$

(e) local response rates on the main key in the presence of each color, *i.e.*,

$$\frac{R_R}{T_R} \text{ and } \frac{R_G}{T_G} \text{ (Local Rates);}$$

(f) relative local response rates in the presence of the red key color, *i.e.*,

$$\frac{R_R / T_R}{R_R / T_R + R_R / T_G} \text{ (Rel Local Rate).}$$

The electric shocks were delivered through electrodes implanted near the pubic bones (Azrin, 1959). The electrodes were held in place by a harness worn at all times by the subject. Shock duration was 50 msec, controlled by an electronic timer. The values of shock intensity employed and their sequence are given in Table 1.

All experimental conditions were arranged through standard relay circuitry. An experimental session would end after the delivery of the sixtieth reinforcement. At least 14 daily sessions were conducted under the same experimental condition. When the proportions of responses on each key color revealed no ascending or descending trends during the last five of these 14 sessions, another experimental condition was introduced. Absence of trends means that the straight line that would fit the five points would be parallel to the horizontal axis when proportions of responses were plotted against sessions. When a trend was observed within the last five sessions of the minimum of 14 conducted, the subject was run on that experimental condition until the criterion was reached. If more than 20 sessions were conducted without reaching stability in relative response rates, the last 10 sessions were taken into consideration. When there was no trend in proportions of responses on these 10 sessions, the experimental condition was changed.

Results

The data presented in Table 1 were taken from the last five sessions in each experimental condition, with three exceptions that can be seen in the second column. In those cases where the stability criterion was not reached after more than 20 sessions, the data from the last 10 sessions were used. In each row, the numbers correspond to the totals for the number of sessions specified in the second column.

Changeover Rates

Figure 1 shows the effect of shock intensity on changeover rates associated with the different schedules of reinforcement. Changeover

Table 1

Original data from Exp. 1 totaled across the last five or 10 sessions (as indicated in the second column).

Shock		*Responses*		*Time (Sec)*		*Reinf*		
(mA)	*Sess*	*Red*	*Green*	*Red*	*Green*	*Red*	*Green*	*CO*
P-1 *conc* **VI 1-min (red) VI 3-min (green)**								
0	5	5517	3449	8022	5874	221	79	4956
4	5	6050	3825	7718	6048	221	79	5903
10	5	8932	1965	9851	4259	226	74	2482
16	5	9893	735	11737	2494	230	70	1168
7	5	8658	2571	8456	5322	224	76	4209
4	5	7497	2362	7290	6569	221	79	4015
0	5	7951	2479	7898	5806	222	78	3564
P-2 *conc* **VI 1-min (red) VI 3-min (green)**								
0	10	13556	7689	19693	8282	448	152	13190
4	5	6719	1834	9809	4369	225	75	1760
7	5	8325	801	11928	2901	233	67	433
10	5	10363	940	11778	4393	234	66	208
7	5	14387	709	12648	1720	234	66	444
4	5	6844	2289	9479	4013	223	77	2864
0	10	14777	7722	18848	8798	449	151	11792
P-3 *conc* **VI 1.5-min (red) 1.5-min (green)**								
0	5	3694	3589	7020	6866	148	152	5800
4	5	4397	3868	6955	6868	148	152	2277
7	5	6134	4347	7745	6087	153	147	1945
10	5	2720	2476	7547	7152	150	150	857
7	5	3335	3045	6855	6844	150	150	2347
P-4 *conc* **VI 1.5-min (red) 1.5-min (green)**								
0	5	2020	2054	7096	7023	150	150	3994
4	5	1601	1604	7021	7095	151	149	3186
7	5	2127	2185	7233	7073	150	150	1736
10	10	7936	8205	16299	18305	293	307	399

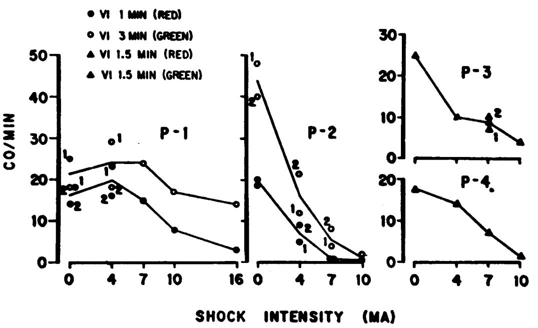

Fig. 1. Changeover rate as a function of shock intensity on concurrent VI VI, shock after changeovers. The numbers (1,2) beside some points indicate first determination and redetermination for that value of shock intensity.

rates can be seen separately for the periods when each key color was present. The rate of changeovers under green, for instance, is given by dividing the total changeovers in a given session by the time spent in the presence of the green key color in that session. It can be seen that the rates of changeovers generally decrease as shock intensity increases. When the concurrent VI schedules are equal, changeover rates are approximately the same under both exteroceptive stimuli (red and green), and are about equally affected by increases in shock intensity. When the concurrent schedules are unequal, the schedule arranging the higher number of reinforcements per hour tends to maintain the lower rate of changeovers. In both cases, changeover rates generally decrease when shock intensity is increased.

Figure 2 shows that the proportion of responses in the presence of the red key color increased with increases in shock intensity when VI 1-min was associated with that color, and VI 3-min was associated with the other color; it did not change systematically when VI 1.5-min was associated with each color. In Fig. 2, the lines connect the points obtained from the ascending series of shock intensity; the unconnected points are those obtained from the descending series. Except for one redetermination (at 7 mA), only the ascending series was used for the subjects on equal VI schedules. This redetermination was made because Subject P-3 was later used in another experiment, which required shock intensity of 7 mA following changeovers.

The effect of shock intensity on the distribution of time in the presence of each color is also shown in Fig. 2. The proportion of time spent in the presence of the exteroceptive stimulus associated with VI 1-min generally increased with increases in shock intensity. For the subjects on equal concurrent schedules, the distribution of time did not change systematically.

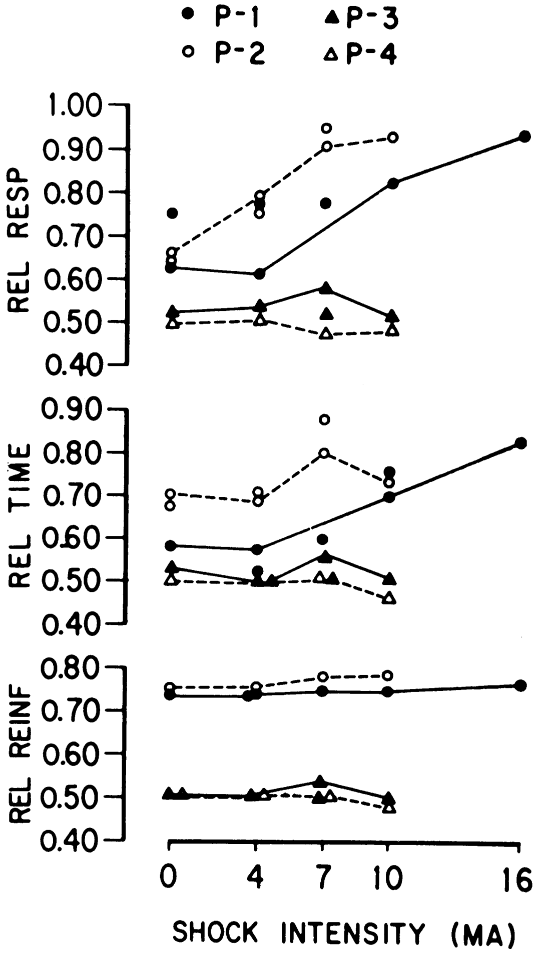

Fig. 2. Relative response rate, relative time, and relative reinforcement rate as a function of shock intensity on concurrent VI VI, shock after changeovers. Circles indicate subjects on *conc* VI 1-min, VI 3-min; triangles indicate subjects on *conc* VI 1.5-min, VI 1.5-min. The lines connect the points obtained from the ascending series of shock intensity.

The lower part of Fig. 2 shows that the distribution of obtained reinforcements did not change systematically with manipulations in shock intensity for all subjects.

Local Rates and Stimulus Control

The effects of shock intensity on response and time distribution can be seen in a different

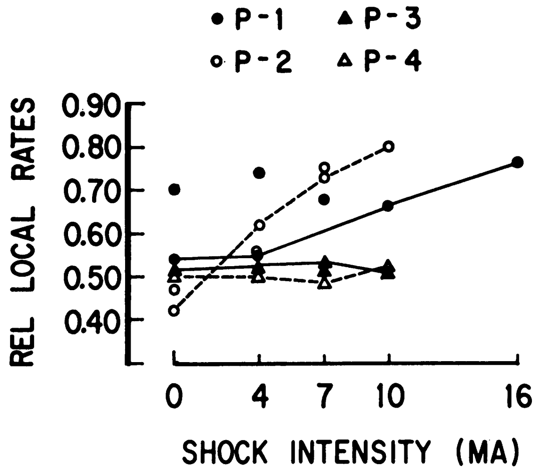

Fig. 3. Relative local response rate as a funtion of shock intensity on concurrent VI VI, shock after changeovers. Circles indicate subjects on *conc* VI 1-min, VI 3-min; triangles indicate subjects on *conc* VI 1.5-min, VI 1.5-min. The lines connect the points obtained from the ascending series of shock intensity.

way in Fig. 3. If the number of responses emitted in the presence of an exteroceptive stimulus is divided by the time spent in the presence of that stimulus, the result is the local response rate in the presence of that stimulus. Thus, it is possible to compute separate rates of responding under the red and the green key colors, for the four subjects. Figure 3 shows that as the shock intensity contingent on changeovers increases, the relative local response rate on the red key tends to increase for those subjects on unequal concurrent schedules [*conc* VI 1-min (red) VI 3-min (green)]. For the subjects on *conc* VI 1.5-min VI 1.5-min there is no systematic change in the relative local response rate as shock intensity is increased. In other words, as shock intensity increases, changeovers decrease in frequency, and the exteroceptive stimuli exert differential control over responding for those subjects on different concurrent schedules. For Subject P-2, there was reversibility of the effect; Subject P-1 maintained different local response rates even when shock intensity decreased to zero. Subject P-1 also shows less recoverability in Fig. 2 (in the relative response data).

Discussion

The data from Exp. 1 show that for subjects on unequal, concurrent VI schedules, the rate of changeovers decreased and the relative response rate in the presence of the key color associated with the VI 1-min schedule increased as shock intensity was increased. By manipulating shock intensity it was possible to obtain relative response rates that would be lower or higher than, or approximately equal to, the relative reinforcement rate. This observation partially supports Shull and Pliskoff's (1967) conclusions concerning the importance of the changeover rate in the determination of concurrent performances. They used rats as subjects, click frequency as discriminative stimuli for the concurrent operants, brain stimulation as the reinforcer, and the changes in changeover rates were obtained after manipulations in changeover delay duration. Shull and Pliskoff showed that the correspondance of the relative rates of responding and the scheduled rates of reinforcement broke down with the changes in changeover delay duration. However, there was still a fairly good correspondance between the rates of responding and the obtained rates of reinforcement.

The present experiment demonstrates that, at least for the conditions in effect during this investigation, the relative response rate can be manipulated even when the relative reinforcement rate is kept approximately the same. The present results clearly demonstrate that for a given pair of concurrent VI VI schedules, the relative response rate is a function of the intensity of shock contingent on changeovers (Fig. 2).

Shull and Pliskoff (1967) observed an isomorphism between relative response rate associated with a schedule and relative time spent responding in the presence of that schedule, and suggested that the relative response rate is indirectly determined by the changeover rate, through the distribution of time spent in the presence of each schedule of the concurrent pair. This relationship has also been suggested by Herrnstein (1961) and Catania (1966) concerning performances in concurrent VI VI schedules with a COD contingency. On the other hand, the present results (Fig. 3) clearly indicate that as shock intensity is increased, the rate of changeovers decreases, time distribution changes, and response distribution changes; but the time distribution does not change in the same way as response distribution changes. The relative rate of responding cannot be explained by time distribution alone, in this case. It seems to result from the joint effect of different changeover rates controlled by the concurrent schedules (Fig. 1) and of different local response rates controlled by those schedules (Fig. 3).

EXPERIMENT 2: PUNISHMENT AND REINFORCEMENT DISTRIBUTION

The present experiment further investigated how concurrent performances are affected when electric shock is contingent upon switching responses. Response distribution was observed for several pairs of unequal variable-interval schedules under conditions of presence and absence of shock, to verify whether the findings of Exp. 1 could be extended to other distributions of reinforcements between the concurrent pair of VI schedules.

METHOD

Subjects

Two adult, male Silver King pigeons, were maintained at 80% of free-feeding weight. Subject P-4 had a previous history of responding in Exp. 1 under equal concurrent VI 1.5-min schedules of reinforcement. P-10 was experimentally naive.

Apparatus

The apparatus from Exp. 1 was used.

Procedure

The general procedure was the same as that followed in Exp. 1, except that several pairs of VI schedules were associated with the main key throughout the experiment. The sum of reinforcements per hour arranged by the two schedules was kept constant at 80 when the pair of schedules was changed. P-4 was first submitted to all pairs of schedules when a 10-mA electric shock of 50 msec duration was delivered after every changeover; then, shock was discontinued and a new sequence of concurrent pairs was scheduled. P-10 had shock contingent upon changeovers in the second part of the experiment only. Each experimental condition was investigated for a minimum of 14 daily sessions of 60 reinforcements.

RESULTS

Table 2 gives a summary of the results. The functions relating proportion of responses to proportion of reinforcements are shown in Fig. 4; the ordinate shows the proportion of responses on a given schedule and the abcissa represents the proportion of reinforcements provided by that schedule.

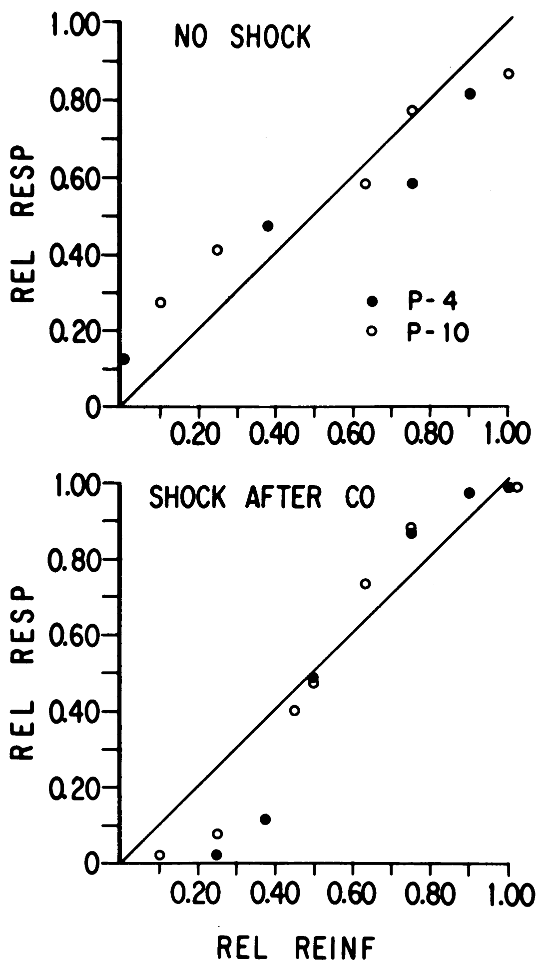

Fig. 4. Response distribution as a function of reinforcement distribution on concurrent VI VI, with and without shock after changeovers. The diagonal line shows matching between the relative measures.

Figure 4 shows that when no shock is contingent upon changeovers, the proportion of responses in the presence of a color is a function of the proportion of reinforcements associated with that color. The diagonal line indicates the points where the proportion of responses would match the proportion of reinforcements. Proportion of responses tended to be higher than the proportion of reinforcements for those schedules arranging the lowest number of reinforcements per hour; the relationship is reversed for those schedules ar-

Table 2

Original data from Exp. 2 totaled across the last five or 10 sessions (as indicated in the third column).

Rft/Hour on VI Schedules Red	Green	*Sessions*	*Responses* Red	Green	*Time (Sec)* Red	Green	*Reinf* Red	Green	*CO*
P-4 Shock after Changeovers									
40	40	10(15)	7936	8205	16299	18305	293	307	399
80	0	5(14)	7206	8	13518	54	300	0	4
20	60	5(33)	240	12986	1345	13346	57	243	284
60	20	5(23)	5997	979	11566	3319	229	71	352
30	50	5(28)	825	6660	2493	12632	89	211	347
72	8	5(21)	9485	272	13250	816	282	18	104
P-4 No Shock									
72	8	5(17)	7434	1702	10576	2863	269	31	2648
30	50	5(23)	3387	3849	6301	6910	114	186	4723
60	20	5(26)	4185	2966	8292	5257	224	76	3424
0	80	5(24)	928	6730	1518	11564	0	300	1688
P-10 No Shock									
60	20	5(14)	6363	1886	11234	2966	229	71	2778
20	60	5(14)	3042	4392	4492	9280	80	220	4021
50	30	5(23)	5643	4045	8607	7623	187	113	6405
8	72	5(23)	3251	8773	3792	9611	32	268	4715
80	0	5(34)	10175	1687	11186	2190	300	0	3158
P-10 Shock after Changeovers									
80	0	5(17)	9564	64	13267	79	300	0	12
20	60	5(28)	1060	12888	3000	11180	72	228	794
60	20	5(18)	13142	1935	10844	3040	227	73	1056
8	72	5(19)	425	20353	1209	12579	25	275	211
50	30	10(31)	20086	7263	17534	10355	378	222	1827

ranging the highest proportions of reinforcements.

Figure 4 also shows that when a 10-mA electric shock of 50 msec duration was delivered after changeovers, the function relating distribution of responses to distribution of reinforcements was S-shaped. For all pairs of unequal variable-interval schedules, most of the responses were emitted under the schedule providing the larger number of reinforcements per hour.

The local rates of responding in the presence of both colors also were affected by the consequences of changeovers. The relative local response rates (local rates under red divided by the sum of local rates under both colors) are shown in Fig. 5. The abcissas represent the relative rates of scheduled reinforcements; the ordinates show the relative local response rates. The graph on the upper part gives the points from the "no-shock" conditions; the points from the "CO-shock" condition are shown on the lower part. Each graph shows the data from both subjects.

Figure 5 shows that in the no-shock condition, the relative local response rate did not change systematically when the concurrent pair of schedules of reinforcement was varied. The subjects tended to respond at about the same rate in the presence of each color, regardless of the proportion of reinforcements assigned to that color. However, when each changeover was followed by shock, the local rate of responding in the presence of a color varied as a function of the proportion of reinforcements provided by the schedule associated with that color.

Discussion

The results from Exp. 2 confirm and extend the findings of Exp. 1 regarding the effects of electric shock contingent on changeovers. The present experiment shows that (a) the reduction of changeover rate through the introduction of electric shocks contingent on changeovers will alter response distribution, as was observed in Exp. 1; and (b) for a given value of shock intensity it is possible to ascertain

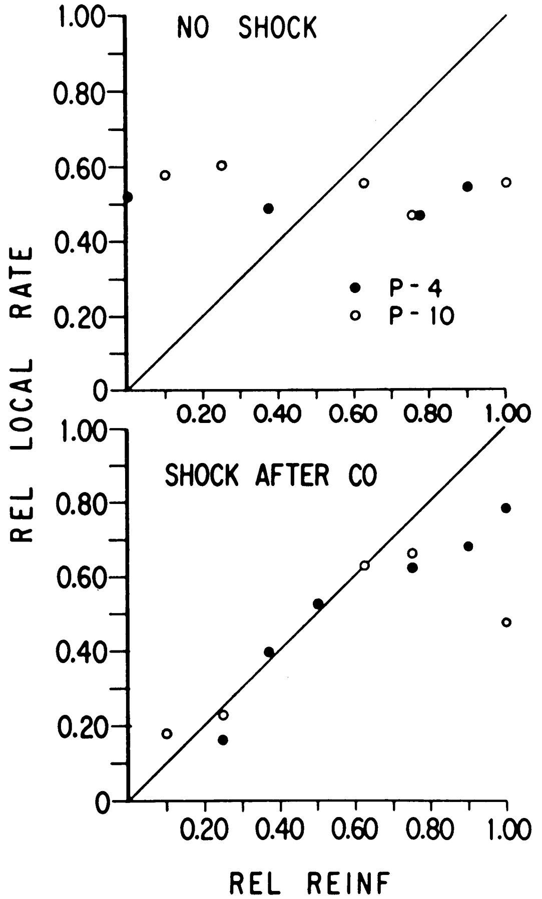

Fig. 5. Relative local response rate as a funtion of reinforcement distribution on concurrent VI VI, with and without shock after changeovers. The diagonal line shows matching between the relative measures.

the form of the function relating proportion of responses to proportion of reinforcements. Considered together, the data from Exp. 1 and 2 indicate that, for any pair of unequal VI schedules, the matching of proportion of responses to proportion of reinforcements may not be obtained under certain conditions of changeover performance.

A comparison between local response rates under the no-shock condition and under the CO-shock condition also confirms the results of Exp. 1 and extends them to other pairs of VI schedules. It can be concluded that for a given number of reinforcements per hour, unevenly distributed between two concurrent VI schedules, the local response rate under each schedule will depend: (a) on the proportion of reinforcements assigned to that schedule, *and* (b) on the intensity of electric shock contingent upon changeovers.

EXPERIMENT 3: TIMEOUT CONTINGENT ON CHANGEOVERS

So far, the changes in response distribution and in local response rate have been shown as results of manipulations in shock intensity contingent on changeovers. The changes in rates of changeovers have been mentioned as a probable link in the chain: increasing shock intensity results in decreasing changeover rates; decreasing changeover rates result in changes in response distribution and in local response rates. The purpose of Exp. 3 was to verify the possibility that similar effects in response distribution and in local response rates could be found when changes in changeover rates were the result of manipulations in a different consequence of switching, timeout from the experimental situation.

Method

Subjects

Three adult, male White Carneaux pigeons were maintained at 80% of free-feeding weight. All had been exposed to a variety of procedures involving schedules of reinforcement.

Apparatus

The apparatus from Exp. 1 and 2 was used.

Procedure

The general procedure was the same as that followed in Exp. 1, except for the use of electric shock. During parts of the present experiment, pecks at the changeover key were followed by a timeout period, during which all lights in the experimental chamber went off and all scheduling and recording devices stopped. The duration of the timeout period was manipulated. Table 3 gives the durations in seconds of timeout periods used, and their order of introduction for each bird. Each experimental condition was investigated for a minimum of 14 daily sessions of 60 reinforcements.

Some experimental findings were redetermined in Exp. 3. The descending series of shock intensities used for P-1 in Exp. 1 resulted in relative response rates that were higher than those resulting from the same shock intensities used in the ascending series. To verify the possibility of a similar effect when a timeout, instead of electric shock, is in force P-12 and P-13 were returned to the condition where no timeout was contingent on changeovers, after being exposed to the timeout contingency. P-12 was returned to that initial condition after being exposed to all four timeout durations used. After reaching the stability criterion on the second determination of relative response rate at 0-sec timeout duration, P-12 remained on that experimental condition for 14 more sessions. The last five of these sessions were considered for a third determination of relative response rate at 0-sec timeout duration. This third determination was undertaken as a check on the stability criterion used. A second determination was made for 3.0-sec timeout duration also, to check the trend in the experimental results that appeared on the first seven experimental conditions.

P-13 was returned to 0-sec timeout duration on the fourth experimental condition because of an interruption of three weeks due to illness. Two other redeterminations were made for P-13, at 1.0 sec and at 3.0 sec, to check the trend in experimental findings that appeared after five experimental conditions.

Because of technical problems, P-15 was run on four experimental conditions only.

Results

The data collected in Exp. 3 are summarized in Table 3.

Changeover Rates

Figure 6 shows the effects of timeout length on changeover rates associated with each schedule of reinforcement. It can be seen that changeover rates generally decrease with increases in length of timeout periods (in logarithmic scale in Fig. 6). As was illustrated in Fig. 1, Exp. 1, the lower rate of changeovers was that in the presence of the schedule arranging the higher number of reinforcements per hour.

The similarity of the effects of shock intensity and timeout length on changeover rates confirms the qualification of timeout as a punishing stimulus when there is an alternative response (Ferster, 1958; Holz, Azrin, and Ayllon, 1963).

Table 3

Original Data from Exp. 3 Totaled across the Last Five Sessions

Timeout	*Responses*		*Time (Sec)*		*Reinf*		
(Sec)	*Red*	*Green*	*Red*	*Green*	*Red*	*Green*	*CO*
P-12 *conc* VI 1-min (red) VI 3-min (green)							
0	2445	2426	9562	4294	220	80	3712
1.0	4407	849	10877	3156	227	73	1394
3.0	5043	774	10915	3008	228	72	845
9.0	5168	502	12343	2088	232	68	460
0.3	4220	988	10575	3152	226	74	1772
0	3962	1135	11127	2998	226	74	1766
0	4120	1250	10389	3406	223	77	2187
3.0	5968	757	11289	2676	227	73	1240
P-13 *conc* VI 1-min (red) VI 3-min (green)							
0	2071	1582	9576	4557	222	78	2626
1.0	2527	789	9313	4860	223	77	1536
3.0	2859	516	10960	3649	226	74	881
0	3325	1822	8744	5090	225	75	3512
9.0	4877	263	12691	1875	236	64	396
3.0	4637	297	12677	2354	235	65	452
1.0	2602	889	10467	4211	223	77	1609
0.3	2008	1213	10074	4212	220	80	2198
P-15 *conc* VI 1-min (red) VI 3-min (green)							
0	3048	2340	9258	4816	222	78	3340
0.3	7444	2187	10353	3573	227	73	1963
1.0	7346	1584	10445	3379	226	74	1359
3.0	10593	442	12622	1763	234	66	608

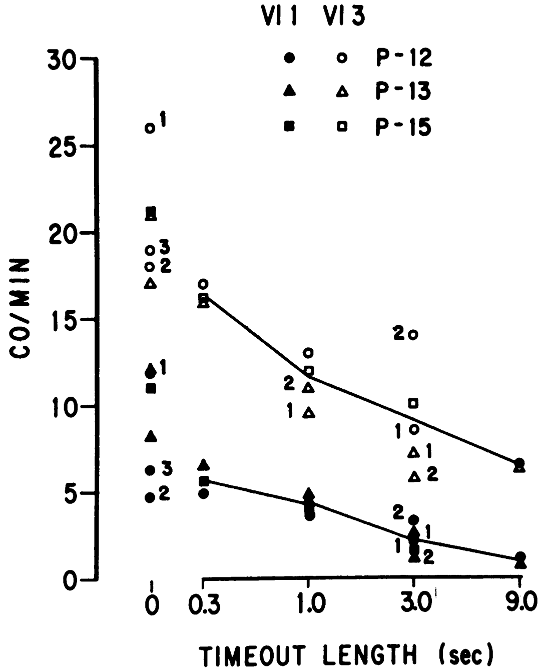

Fig. 6. Changeover rate as a function of timeout length on concurrent VI VI, timeout after changeovers. The numbers beside some points indicate first, second, or third determination for that value of timeout length.

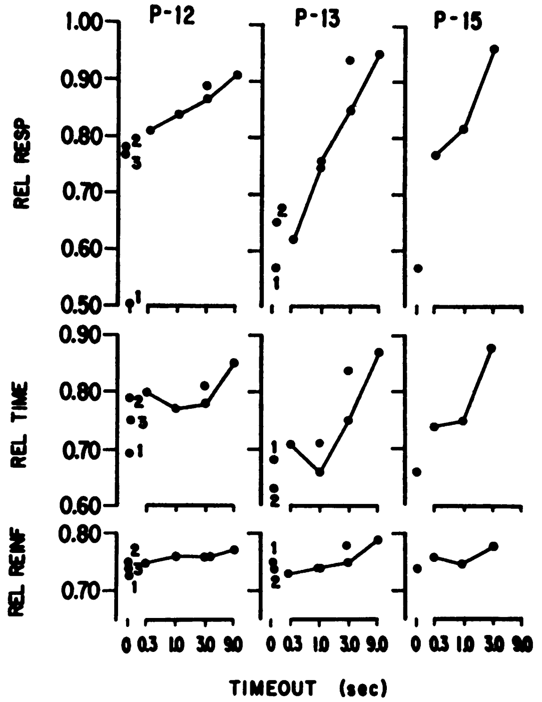

Fig. 7. Relative response rate, relative time, and relative reinforcement rate as a function of timeout length on *conc* VI 1-min, VI 3-min, timeout after changeovers. The lines connect the points obtained on the first determination at each timeout duration. The numbers beside some points indicate first, second, or third determination for that value of timeout length.

Relative Performance Measures

Figure 7 shows that the proportion of responses in the presence of the key color associated with the VI 1-min increases with increases in timeout length for all subjects. The distribution of time, also shown in Fig. 7, shows similar effects of timeout length for Subjects P-13 and P-15. The effect of timeout length on time distribution for Subject P-12 is less clear, although there seems to be an ascending trend for the last four points on the graph. Figure 7 also depicts the effects of timeout length on the distribution of obtained reinforcements. Visual inspection shows a trend in the points, with distribution of reinforcements being systematically affected by timeout lengths, but the maximum deviation from the scheduled proportion (0.75) for the red color was 0.04 for P-13.

Local Rates and Stimulus Control

Figure 8 shows the effects of timeout length on relative local response rates. For all subjects, as timeout length is increased, the relative local response rate associated with the VI

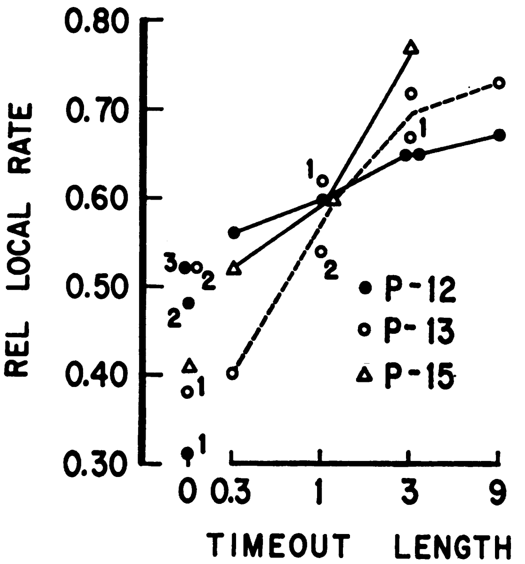

Fig. 8. Relative local response rate as a function of timeout length on *conc* VI 1-min, VI 3-min, with timeout after changeovers. The numbers beside some points indicate first, second, or third determination for that point.

1-min schedule increases. As was the case for the subjects on unequal, concurrent VI VI schedules in Exp. 1, as the rate of changeovers decreases, response rates under VI 1-min seem to increase, and response rates under VI 3-min seem to decrease, generally.

Discussion

The data from Exp. 3 seem to be comparable to corresponding results in Exp. 1. It was shown that when changeover rates are decreased through manipulation of the length of timeout periods contingent on switching responses, the effects on time distribution, on response distribution, and on local response rates are similar to results obtained when a brief electric shock is delivered contingent on changeovers. When the results from Exp. 2 are also considered, there is strong evidence indicating that the relative rate of responding will be higher or lower than, or equal to, the relative rate of reinforcement depending on the intensity of shock or on the length of a timeout period contingent on changeovers.

These results lead to some questions regarding recent developments on quantitative relationships in concurrent VI VI schedules. A matching relationship between relative rate of responding and relative rate of reinforcement has been observed (Catania, 1963, 1966; Herrnstein, 1961; Stubbs and Pliskoff, 1969); it was also found that pigeons match relative time and relative rate of reinforcement (Baum and Rachlin, 1969; Brownstein and Pliskoff, 1968; Catania, 1966; Stubbs and Pliskoff, 1969). In all these experiments, a COD was used to secure the matching relationship. It has been generally suggested that the distribution of time is the basic process in the matching equation (Baum and Rachlin, 1969; Brownstein and Pliskoff, 1968; Catania, 1966; Shull and Pliskoff, 1967; Stubbs and Pliskoff, 1969). The local rates of responding would be the same under both concurrent schedules, so that when the relative time spent in the presence of a stimulus is determined, the relative overall rate of responding, as a by-product, is also determined. The crucial factor in matching would be the difference in changeover rates under each schedule of the concurrent pair. This interpretation received support from data from Catania (1966) and Stubbs and Pliskoff (1969). They presented evidence showing that when a COD is used, local response rates tend to be about the same under both schedules. Consequently, the relative local rate of responding would vary around 0.50. Stubbs and Pliskoff showed that manipulations in COD duration do not alter the relative local response rate systematically.

However, the present data and results from Shull and Pliskoff (1967) suggested the possibility that any independent variable that can reduce the frequency of changeovers on *conc* VI x-min, VI y-min ($x \neq y$) will affect the relative overall rate of responding. It is suggested also that the relative overall rate of responding will be determined by: (a) different rates of changeovers in the presence of each schedule, which will determine time distribution, *and* by, (b) different local rates of responding in the presence of each schedule—the difference will increase as changeovers decrease in frequency.

The difference in changeover rates can be understood when the analysis of concurrent responding made by Catania (1966, p. 228) is repeated for the case of unequal VI schedules instead of equal concurrent VI VI. The difference in local response rates seems to be related to the development of stimulus control exerted by the key colors associated with each schedule. Given any procedure that will reduce changeover rates (and consequently increase the time of exposure to each VI schedule between switchings), responding under each schedule will come to be more under the control of the rate of reinforcement provided by that schedule. Responding under any given schedule in concurrent VI VI will become more like responding under that schedule in a single-key procedure.

It is not yet possible to explain why the data from experiments using a COD cannot fit into the above suggestion. Item (b) is not true for those experiments. However, it is known that, in a way, a COD does change local response rates after changeovers. Silberberg and Fantino (1970) verified that responding under each schedule could be divided into two parts when a COD was used. After a changeover, the subjects would start a rapid response burst with a length proportional to COD duration. If the subject continued responding on the same key after the initial burst of responses, it would respond at a lower rate. Thus, the local rate of responding on a given schedule would be the average of periods of rapid response bursts (following changeovers) and periods of responding that were more characteristic of performances under VI schedules. If the local rates were calculated by dividing responses under a given schedule by the time spent in the presence of that schedule, they would be about the same for both VI schedules. But if only responses emitted after the initial burst and the time after that burst were taken into consideration, local response rates would be different under the concurrent schedules; the higher local response rate would be associated with the most favorable VI schedule, as was observed in the present investigation.

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